Arizona
Department of Transportation

WORKBOOK

for

FIELD SAMPLING AND TESTING FOR EARTHWORK CONSTRUCTION (Course Number 101)

a training course developed
for the

ARIZONA DEPARTMENT OF TRANSPORTATION
Phoenix, Arizona

by

ROY JORGENSEN ASSOCIATES, INC.
Gaithersburg, Maryland

Revised by ADOT – October 20, 2006

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Directions To Workbook Users

Field Sampling and Testing for Earthwork (Course Number 101) is one in a series of training courses on inspection for earthwork incidentals in highway construction. Other courses in the series include:

- Excavation and Embankment Inspection (Course 102),
- Pipe Placement Inspection (Course 103),
- Subgrade, Base Course Inspection (Course 104), and
- Earthwork Incidental (Course 105).

This course is designed primarily for highway construction inspection personnel, but it can also be used in training other personnel.

This workbook is to be used in conjunction with discussion sessions with the trainee's instructor or supervisor, and other materials that make up the course. As sections of this workbook are assigned, each trainee should:

1. read and study the material to review previously presented information and gain additional details,
2. complete the exercises and quizzes as they are provided,
3. check answers against those provided following the exercise or quiz,
4. review the material as needed to correct and clarify any incorrect answers, and
5. discuss any areas that are still not clearly understood with the instructor or supervisor.

Each trainee should be provided with his own copy of this workbook so that he can write in it and keep it for future reference and review. This course is based primarily on the sampling and testing methods established in ADOT's *Materials Testing Manual*. Each respective section of the manual is identified in this Workbook. Users of this Workbook should refer to the appropriate section of the *Materials Testing Manual* for additional information.

This course is useful in helping personnel to prepare for ATI testing. Although not specifically designed or organized as training for ATI testing, this course relates to the earthwork construction aspects of ATI non-testing elements related to inspection.

Section One: Introduction

Soils and aggregates play critical roles in highway construction – particularly in roadway embankments, subgrades and bases. This section reviews certain introductory aspects of soils and aggregates, including:

- their characteristics, and
- basic density relationships.

Characteristics of Soils and Aggregates

There are many different types and classifications of soils and aggregates based on a wide variety of materials characteristics. However, from the standpoint of earthwork inspection, there are several key characteristics that are particularly significant. These include the following terms that are defined below. See also the Glossary of Terms in the ADOT Materials Testing Manual:

- gradation;
- moisture content;
- density; and
- others, such as plasticity, fractured coarse aggregates, pH value and resistivity.

Gradation

The gradation of a material refers to the sizes of the particles in that material. In road construction, a material that has particles that are all about the same size will react very differently from a material that includes a mixture of coarse, intermediate, and fine particles.

Moisture Content

The amount of water in soils and aggregates also affects their performance in road construction. For example, there is obviously a big difference between a dry sand, with little or no moisture between the particles, and a mud, where the particles are surrounded by water.

Density

The density of a soil or aggregate is probably its most important characteristic. Density is expressed in terms of the material's weight-per-volume ($D = W/V$) such as pounds per cubic foot. Generally, a denser material is more stable in road construction than one that is less dense.

Other Characteristics

Although there are many other characteristics of soils and aggregates, those that are particularly relevant in earthwork construction include:

- plasticity index – the numerical difference between the material's liquid limit and plastic limit;
- pH – the relative acidity or alkalinity of the materials with 7 being neutral, 0 to 6 being acidic, and 8 to 14 being alkaline;
- resistivity – the tendency of the material to cause corrosion by electrolysis; and
- fractured coarse aggregate particles – the shape of the particles in terms of their mechanically crushed faces.

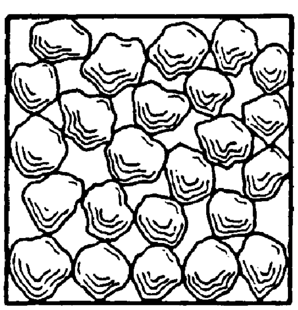
Density Relationships

As we mentioned earlier, density is probably the most critical characteristic of soils as it relates to roadway construction. Additionally, there are direct relationships between a material's density and certain other of its characteristics. The density of a material is particularly dependent on:

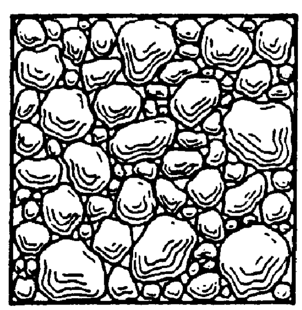
- its gradation,
- its moisture content, and
- the amount of compactive effort applied.

Gradation Relationships

The illustrations below show the difference between a soil with good gradation and a soil with poor gradation. The soil on the left is composed of particles of the same size. There are many air voids in the soil, and as a result, the soil is less dense and would be less stable. The soil on the right, however, has a good mixture of large and small particles. The small particles fill many of the air voids, making the soil denser and more stable.



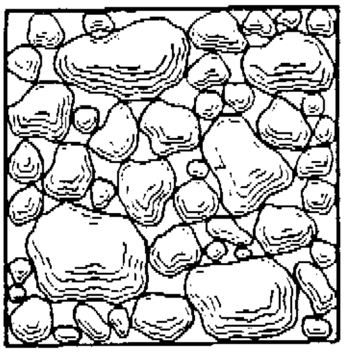
Poor Gradation



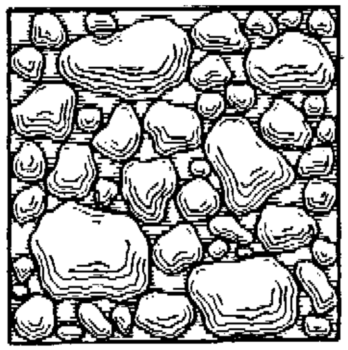
Good Gradation
(Well Graded)

Moisture Relationships

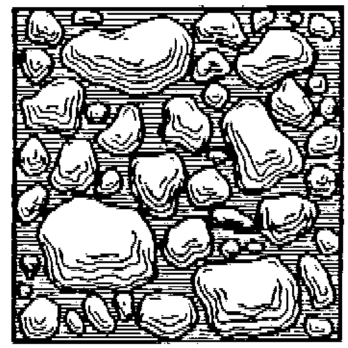
The amount of water in the material directly affects its density and stability. Very dry soil becomes powdery, and very wet soil becomes mud. The proper amount of water, however, can act as an adhesive – bonding the particles of soil together. Moisture content is expressed as a percent of the weight of the soil. The illustrations below show different amounts of water in soil.



Too Dry – particles rest loosely against each other



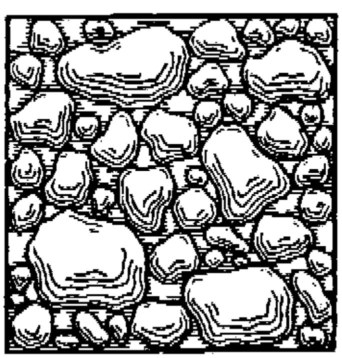
Proper Moisture – moisture helps hold particles together



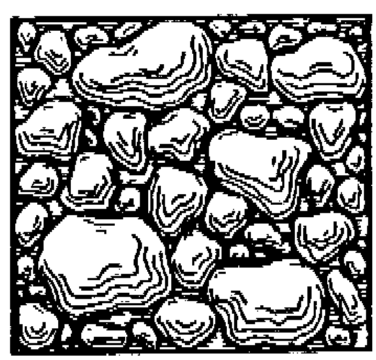
Too Wet – particles tend to "float" in liquid

Compactive Effort

Given soil that has the proper gradation and moisture content, the final way to make it more dense is to compact it using equipment such as rollers, vibrators and tampers to eliminate as many air voids as possible. In the illustrations below, you can see the effect of compaction. Obviously we cannot eliminate all of the voids, but the soil in the right-hand illustration is more dense than any shown above – and would be a better foundation for a street or highway.



Before Compaction – numerous voids



After Compaction – few voids

Section Two: Sampling and Lab Tests

This section reviews the procedures for sampling soils and aggregates from the roadway and provides an overview of certain key tests that are performed in the lab.

Sampling Soils and Aggregates

(Arizona – 105b)

Most soils and aggregates for earthwork operations are sampled directly from the roadway – more specifically from windrows and from in-place situations.[1] Refer to Materials Testing Manual for procedures.

Sampling from Windrows

The primary objective in sampling soils or aggregates from a windrow is to try to collect the sample from the middle portion of the windrow, where it is less likely to be segregated.

At each point in the windrow where a sample is to be taken, remove sufficient material to obtain a representative sample from the middle portion of the windrow using a square point shovel. The sample taken at each sampling location shall be one shovelful of material. Repeat the sampling as necessary, at the required number of locations in the windrow, to obtain the desired amount of material. The samples taken shall be combined.

Sampling from In-Place Situations

When sampling soils or aggregates from in-place situations, the sample should be collected by:

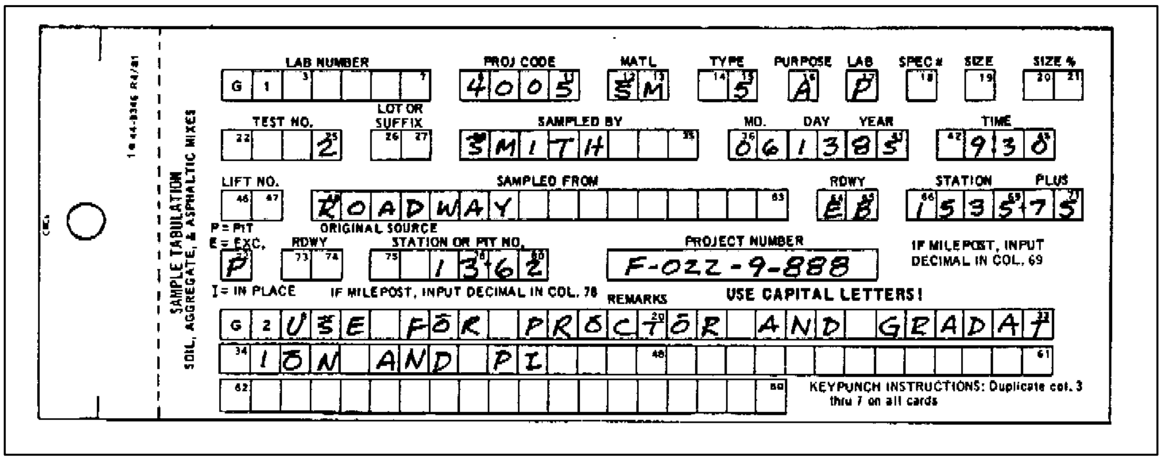
1. using at least three sub-sample locations equally spaced across the roadway;
2. at each sub-sample location:
   - digging a hole in the material, and
   - being sure to include all of the material from the hole (including the fines) in the sample; and
3. combining and blending the material.

[1] Some aggregates are also sampled from conveyor belts or stockpiles at a crusher plant. However, these samples are usually collected by materials personnel. For additional information on these sampling methods, see **Field Sampling and Testing for Bituminous Construction** (Course 301).

Sample Identification

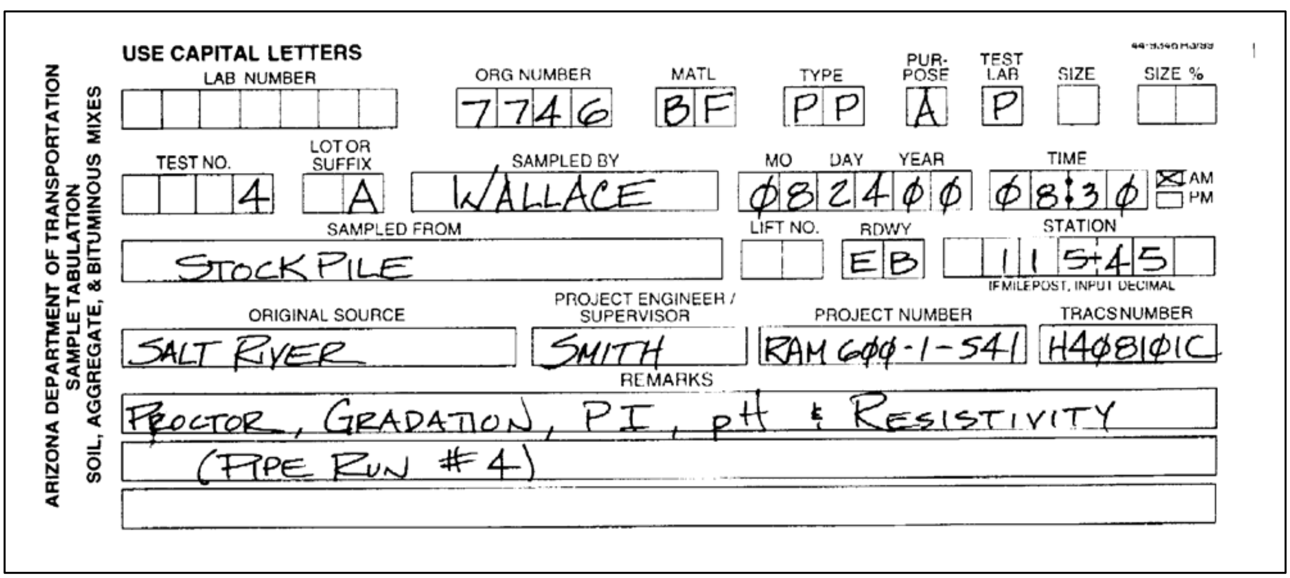
All samples must be clearly labeled to identify the project, the type of material, the purpose of the sample, the date and time sampled, the source of the sample, the person who collected the sample and the tests to be performed.

Two completed Sample Tabulation cards are provided as examples, one from FAST and the other is the standard card. ***However, because the codes on the reverse side of the sample card do not match the FAST Program, use the codes in FAST until the Materials Manual is corrected.*** You can also use the table with correct FAST codes beginning on page 7 of this workbook.



SAMPLE TABULATION
SOIL, AGGREGATE, & ASPHALTIC MIXES

LAB NUMBER: G 1
PROJ CODE: 4005
MATL: SM
TYPE: 5
PURPOSE: A
LAB: P
SPEC #
SIZE
SIZE %
TEST NO.: 2
LOT OR SUFFIX
SAMPLED BY: SMITH
MO. DAY YEAR: 06 13 85
TIME: 930
LIFT NO.
SAMPLED FROM: ROADWAY
RDWY: EB
STATION PLUS: 1535+75
P = PIT
E = EXC.
I = IN PLACE
ORIGINAL SOURCE: P
RDWY
STATION OR PIT NO.: 1362
IF MILEPOST, INPUT DECIMAL IN COL. 78
PROJECT NUMBER: F-022-9-888
IF MILEPOST, INPUT DECIMAL IN COL. 69
REMARKS
USE CAPITAL LETTERS!
G 2 USE FOR PROCTOR AND GRADAT
ION AND PI
KEYPUNCH INSTRUCTIONS: Duplicate col. 3 thru 7 on all cards



ARIZONA DEPARTMENT OF TRANSPORTATION
SAMPLE TABULATION
SOIL, AGGREGATE, & BITUMINOUS MIXES
USE CAPITAL LETTERS
LAB NUMBER
ORG NUMBER: 7746
MATL: BF
TYPE: PP
PUR-POSE: A
TEST LAB: P
SIZE
SIZE %
TEST NO.: 4
LOT OR SUFFIX: A
SAMPLED BY: WALLACE
MO DAY YEAR: 08 24 00
TIME: 08:30 AM
SAMPLED FROM: STOCKPILE
LIFT NO.
RDWY: EB
STATION: 115+45
IF MILEPOST, INPUT DECIMAL
ORIGINAL SOURCE: SALT RIVER
PROJECT ENGINEER / SUPERVISOR: SMITH
PROJECT NUMBER: RAM 600-1-541
TRACS NUMBER: H40810IC
REMARKS
PROCTOR, GRADATION, PI, pH & RESISTIVITY
(PIPE RUN #4)

FAST Material and Type Codes

Material Code	Material Description	Material Type	Type Description
AA	Arrestor Bed Aggregate		
AB	Aggregate Base	1	Class 1
AB	Aggregate Base	2	Class 2
AB	Aggregate Base	3	Class 3
AC	Asphaltic Concrete	12	1/2" Asphaltic Concrete
AC	Asphaltic Concrete	34	3/4" Asphaltic Concrete
AC	Asphaltic Concrete	BM	Base Mix
AC	Asphaltic Concrete	BB	Bituminous Treated Base
AC	Asphaltic Concrete	FC	ACFC
AC	Asphaltic Concrete	OT	Other
AC	Asphaltic Concrete	RC	Recycled Asphaltic Concrete
AC	Asphaltic Concrete	RD	Asphalt Rubber Asphaltic Concrete
AC	Asphaltic Concrete	RF	Asphalt Rubber A.C. Friction Course
AC	Asphaltic Concrete	RM	Road Mix
AD	Admix		
AG	Aggregate	BB	Bituminous Treated Base
AG	Aggregate	CB	Cement Treated Base
AG	Aggregate	CS	Cement Treated Subgrade
AG	Aggregate	LC	Lean Concrete Base
AG	Aggregate	LS	Lime Treated Subgrade
AG	Aggregate	RM	Road Mix
AG	Aggregate	SC	Soil Cement
AS	Aggregate Subbase	4	Class 4
AS	Aggregate Subbase	5	Class 5
AS	Aggregate Subbase	6	Class 6
BF	Backfill	PP	Pipe
BF	Backfill	SL	Slurry
BF	Backfill	SP	Special
BF	Backfill	TR	Trench
BL	Blotter Material		
BM	Bedding Material	CP	Concrete Pipe
BM	Bedding Material	MP	Corrugated Metal Pipe
BM	Bedding Material	PV	PVC Pipe
BW	Borrow		
CA	Coarse Aggregate	1	Size 1
CA	Coarse Aggregate	10	Size 10
CA	Coarse Aggregate	2	Size 2
CA	Coarse Aggregate	24	Size 24
CA	Coarse Aggregate	3	Size 3
CA	Coarse Aggregate	357	Size 357
CA	Coarse Aggregate	4	Size 4
CA	Coarse Aggregate	467	Size 467
CA	Coarse Aggregate	5	Size 5
CA	Coarse Aggregate	56	Size 56

Material Code	Material Description	Material Type	Type Description
CA	Coarse Aggregate	57	Size 57
CA	Coarse Aggregate	6	Size 6
CA	Coarse Aggregate	67	Size 67
CA	Coarse Aggregate	68	Size 68
CA	Coarse Aggregate	7	Size 7
CA	Coarse Aggregate	78	Size 78
CA	Coarse Aggregate	8	Size 8
CA	Coarse Aggregate	89	Size 89
CA	Coarse Aggregate	9	Size 9
CA	Coarse Aggregate	NA	Composite Samples
CB	Crash Barrel Sand		
CM	Cover Material		
CS	Cement Stabilized Alluvium		
DG	Decomposed Granite		
EM	Embankment		
ET	Entrained Air		
FA	Fine Aggregate		
FF	Flyash		
FM	Filter Material		
GM	Granite Mulch		
GR	Granulated Rubber		
GT	Grout		
HO	Water		
MA	Mineral Aggregate	12	1/2" Asphaltic Concrete
MA	Mineral Aggregate	34	3/4" Asphaltic Concrete
MA	Mineral Aggregate	BM	Base Mix
MA	Mineral Aggregate	FC	ACFC
MA	Mineral Aggregate	OT	Other
MA	Mineral Aggregate	RC	Recycled Rubber Asphaltic Concrete
MA	Mineral Aggregate	RD	Asphalt Rubber Asphaltic Concrete
MA	Mineral Aggregate	RF	Asphalt Rubber A.C. Friction Course
MS	Membrane Seal		
NG	Natural Ground		
NM	Pneumatically Placed Mortar		
OT	Other		
PM	Pipe Plating		
RR	Rip Rap		
SB	Structural Backfill		
SG	Subgrade		
SL	Slurry	38	3/8" Aggregate
SL	Slurry	4	#4 Aggregate
SS	Subgrade Seal		
TS	Top Soil		
WC	Winter Cinders		

Lab Tests

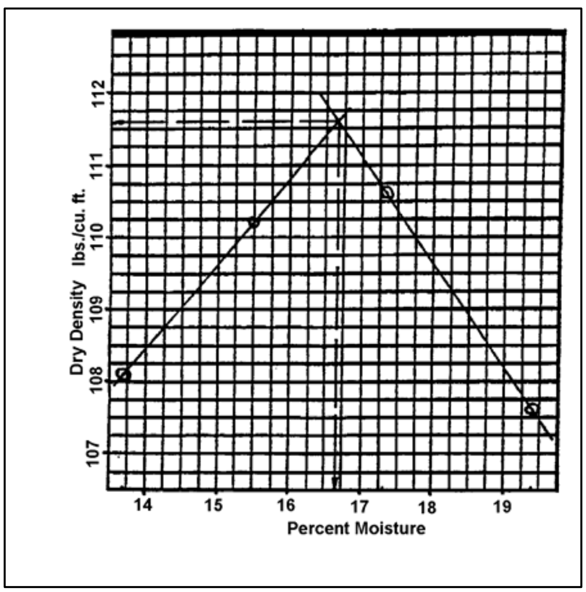
There are a number of tests on soils and aggregates that are typically conducted in a central, regional, consultant or project lab – usually by materials specialists. Although an earthwork inspector would rarely perform all of these tests himself, he should be generally familiar with certain key lab tests on soils and aggregates. The basic procedures will be covered in the ATI Training.

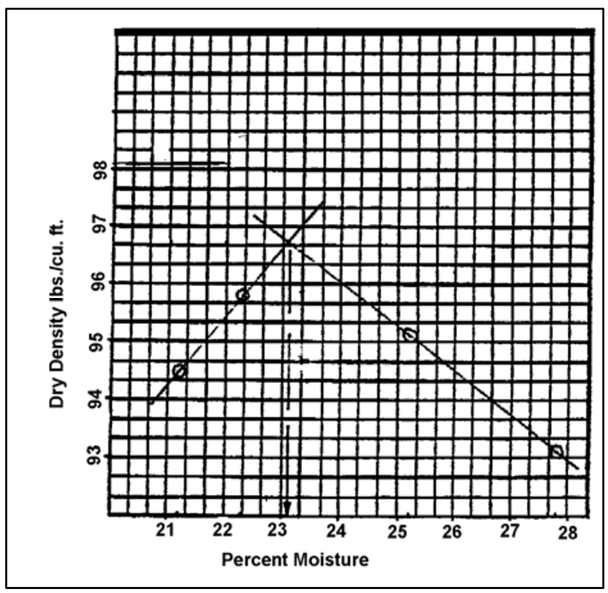
Gradation Testing (Arizona Test Method 201c)

Gradation testing is used to determine the proportions of different sizes of particles in soils and aggregates.

Proctor Test (Arizona Test Method 225a)[2]

The Proctor test is used to determine the maximum density and optimum moisture of soils. Because these values are used to establish basic criteria for compaction and acceptance of earthwork, the Proctor test is particularly critical. Two standard Moisture-Density Curves are shown below:





[2] This section concentrates on the basic, "Method A" Proctor test covered by Arizona-225. However, Arizona-226 covers "Methods C & D" variations for volcanic cinders, while Arizona-227 is used to determine a rock correction factor for plus-#4 material. Additionally, Arizona-221 and -222 provide variations in the Proctor and rock correction for cement-treated mixtures.

Plasticity Index (AASHTO T-89 and T-90)

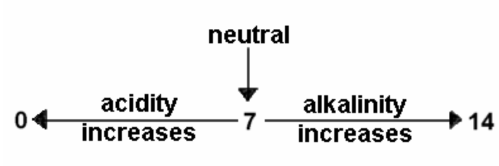
The Plasticity Index (P.I.) is the numerical difference between the material's Liquid Limit (L.L.) at which it passes from a liquid to plastic state, and its Plastic Limit (P.L.) at which is passes from a plastic to solid state.

pH and Resistivity (Arizona-236b)

Both the pH and resistivity of a soil reflect its tendency to corrode such metal items as corrugated metal culverts.

The pH value measures its alkalinity or acidity such that a pH value of:

- less than 7 indicates acidity,
- 7 is neutral, and
- more than 7 indicates alkalinity.



The resistivity part of the test measures the soil's corrosive tendencies through electrolysis.

Crushed Faces (Arizona-212)

The crushed faces test is used to determine the shape of the aggregate particles in terms of their mechanically-crushed surfaces. The tests consists of:

- sieving out a representative portion of particles for examination,
- visually examining each particle for mechanically-crushed faces, and
- calculating the percent (by weight) of particles with at least one mechanically-crushed face.

Section Two Quiz

1. Which of the following characteristics of soils and aggregates is the most important as an end result in earthwork operations? (Circle one)
   a. plasticity
   b. gradation
   c. density
   d. pH value
   e. moisture content

2. Which of the following statements best reflects the relationship between gradation and density? (Circle one)
   a. Larger aggregates are usually heavier and therefore more dense than smaller aggregates.
   b. A well-graded soil is one that includes only particles that are about the same size.
   c. The smaller particles in a mixture of fine and coarse aggregates help fill the voids between the larger particles.

3. When sampling soils or aggregates from windrows at the roadway, the primary objective is to ... (Circle one)
   a. collect at least 8 sub-samples.
   b. take sub-samples from the top, bottom, both sides and each end of the windrow.
   c. select a windrow that is small enough to easily sample.
   d. obtain the sample from the middle of the windrow, so that it is representative.

4. In order to compact soils and aggregates to their maximum dry density, the moisture content should be ... (Circle one or more)
   a. as low as possible, because small amounts of moisture make the particles slippery.
   b. at or near the optimum moisture for the material.
   c. as high as possible, because water is heavier and denser than soil.
   d. high enough to fill part of the voids between particles, but low enough so that particles do not float and slide against each other.
   e. at or near the Liquid Limit for the material.

5. The Plasticity Index of a soil is determined by using variations in the material’s ... (Circle one or more)

   a. gradation
   b. compaction
   c. pH value
   d. resistivity
   e. moisture content

6. Which of the following lab tests is used to determine the corrosive tendencies of a soil? (Circle one or more)

   a. Resistivity test
   b. Proctor test
   c. Crushed Faces test
   d. pH test
   e. Gradation

7. The Proctor test is used to determine a soil’s or aggregate’s ... (Circle one or more)

   a. distribution of different size particles.
   b. optimum moisture for compaction.
   c. range of moisture contents in a plastic state.
   d. proportion of mechanically-crushed particles.
   e. maximum dry density after compaction.

8. Which of the following lab tests establishes the basic criteria for the density of the material used in an embankment? (Circle one or more)

   a. Crushed Faces
   b. pH and Resistivity
   c. Proctor
   d. Plasticity Index
   e. Gradation

Section Two Quiz Answers

1. c. density

2. c. The smaller particles in a mixture of fine and coarse aggregates help fill the voids between the larger particles.

3. d. obtain the sample from the middle of the windrow, so that it is representative.

4. b. at or near the optimum moisture for the material.
   d. high enough to fill part of the voids between particles, but low enough so that particles do not float and slide against each other.

5. e. moisture content

6. a. Resistivity test
   d. pH test

7. b. optimum moisture for compaction
   e. maximum dry density after compaction

8. c. Proctor

Section Three: Field Testing

This section reviews the purposes and procedures for soils and aggregate tests that are conducted in the field for earthwork operations, including:

- the speedy moisture test,
- density testing by sand cone,
- the one-point Proctor test.

Speedy Moisture Test

(AASHTO T-217)

The Speedy[3] moisture test is used to determine the moisture content of soils by means of a chemical reaction with calcium carbide. Because it is a relatively quick test procedure for moisture content, it is commonly used in the field, where determining the moisture by drying to a constant weight would not be practical.

The equipment and materials used in the Speedy moisture test include:

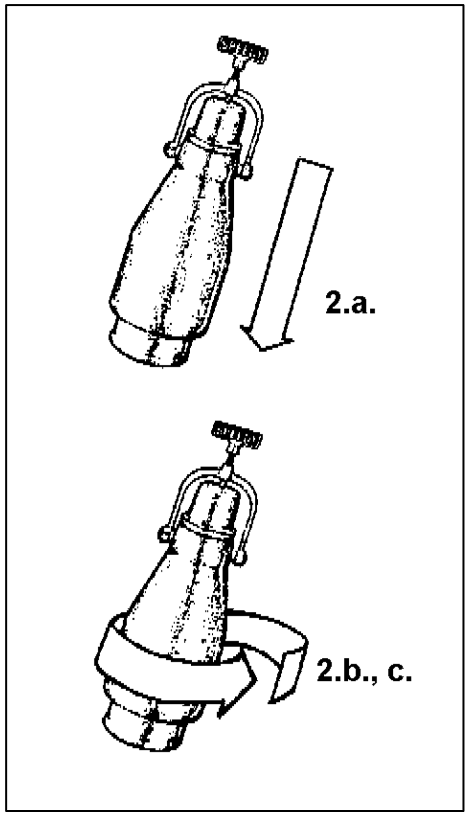
- a calcium carbide pressure moisture tester of either a 6-gram or 26-gram sample size,
- calcium carbide reagent,
- a reagent measuring scoop,
- two steel balls of 1-¼ diameter,
- a balance scale pre-set to measure either 20 or 26 grams (depending on the size of the tester),
- a brush for fines, and
- a cleaning brush and cloth.

The procedures for conducting the Speedy moisture test are summarized in the following steps.

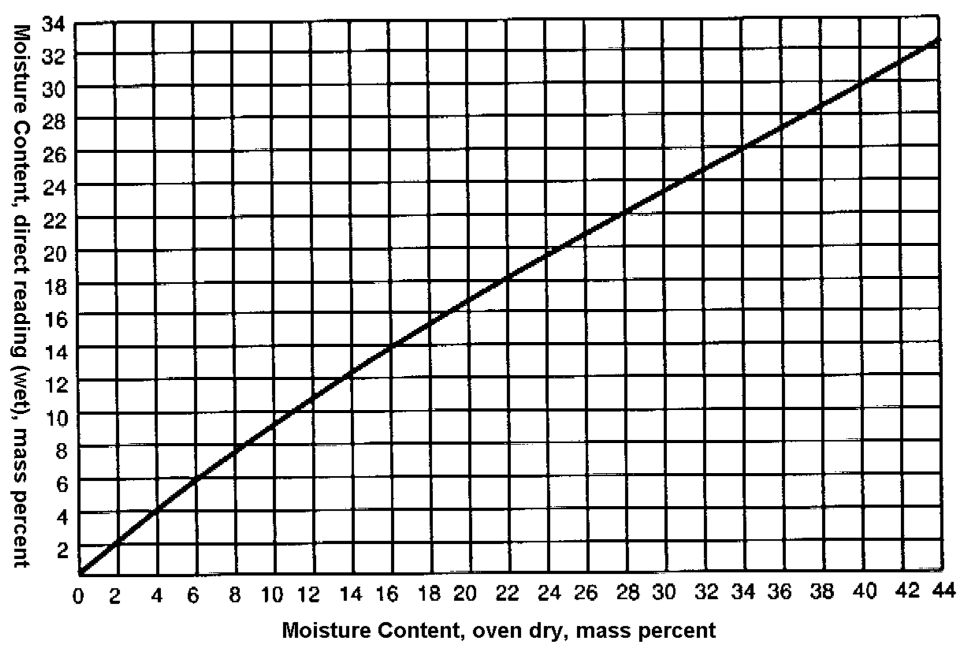
1. **Prepare the Tester** by:
    a. placing reagent in the tester – + three scoops – and the 2 steel balls – for the 20-gram or 26-gram tester (holding the tester in a horizontal position to avoid damage from dropping the steel balls),
    b. weighing a 20- or 26-gram sample on the balance scale and placing it in the cap of the tester,
    c. placing the cap on the tester while holding it horizontal (to avoid contact between the soil and reagent before the tester is sealed), and
    d. closing and tightening the clamp to seal the cap in place.

[3] "Speedy" is the manufacturer's name for the testing equipment used. However, it is commonly used in referring to any calcium carbide gas pressure moisture tester.

2. **Agitate the Tester** by:
   a. turning the tester to a vertical position so that the sample falls from the cap to mix with the reagent,
   b. then:
      - vigorously shaking the tester horizontally, and
      - agitating the tester so that the balls orbit the interior without damaging the tester, and
   c. continuing to agitate the tester for 1 to 3 minutes to ensure that all lumps are broken up,



3. **Read the Dial** by:
   a. turning the tester horizontal, so that the dial in the bottom is visible, and
   b. reading and recording the moisture content (by % of the wet mass) when the needle stops.
4. **Release the Pressure and Clean the Tester** by:
   a. holding the top of the tester away from you and down wind, turning your head away, releasing the pressure slowly and emptying the contents,
   b. examining the contents for any lumps of the material (and retesting, if any are found), and
   c. cleaning the equipment.
5. **Determine the Dry Mass Moisture Content** by converting the wet mass direct reading into the dry mass % from the conversion chart provided with the tester. This may be a conversion curve similar to the one shown below or a numerical table of equivalent wet and dry mass moisture contents.



Speedy Moisture Conversion Curve

Field Density Testing

The in-place density of compacted soils and aggregates is tested in the field by the sand cone which requires:

- digging a hole in the in-place material,
- determining the volume of the hole and weight of the material removed,
- determining the moisture content of the material removed,
- calculating the dry density of the in-place material for comparison with the maximum dry, and
- density established by Proctor testing.

Sand Cone Field Density (Arizona-230)[4]

The equipment and materials used for the sand cone density test include:

- The sand cone apparatus, including the:
  - base plate,
  - metal cone (with valve), and
  - 1-gallon sand jar;
- standard sand (kept dry and free-flowing);
- digging tools (including hammer and chisel, scoop, small spoon for fines, etc.);
- air-tight sample containers;
- a balance scale; and
- Speedy (or other) moisture testing equipment.

Both the sand cone apparatus and the supply of standard sand to be used must be calibrated before density tests can be conducted. The calibration process includes:

- determining the density (lbs./cu. ft.) of the standard sand:
  - using a calibration mold, and
  - calculating the average of 3 trials; and
- determining the volume of the sand cone:
  - by conducting the test on a uniform, flat surface with a base plate, and
  - calculating the average of 3 trials.

The procedures for determining density by the sand cone method include the following:

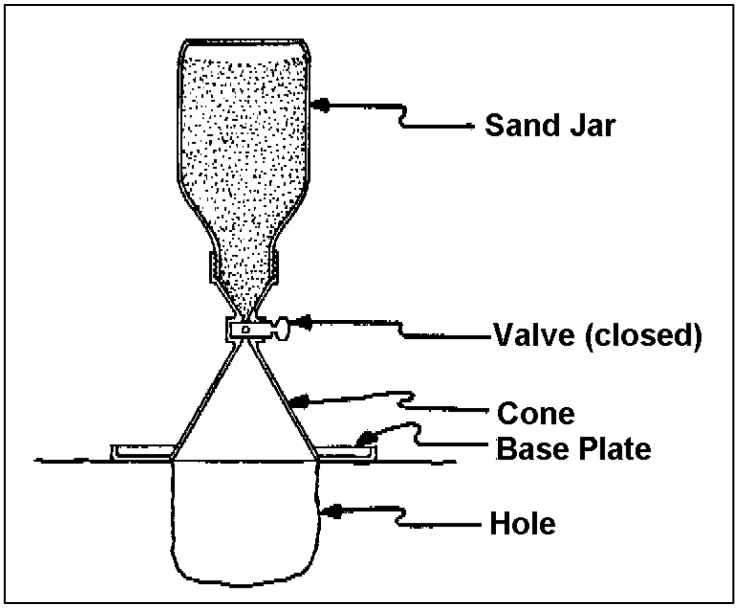
1. **Prepare the Test Site** by:
   a. cleaning away loose soil and rock from a 3-foot square area;
   b. leveling the surface for the base plate;
   c. placing the base plate on the leveled surface;
   d. digging a hole:
      - with a diameter about the same as that of the hole in the base plate,
      - to about 6 inches deep but no deeper than the lift, and

[4] Arizona-229 is also used for calibration of the sand cone and sand.

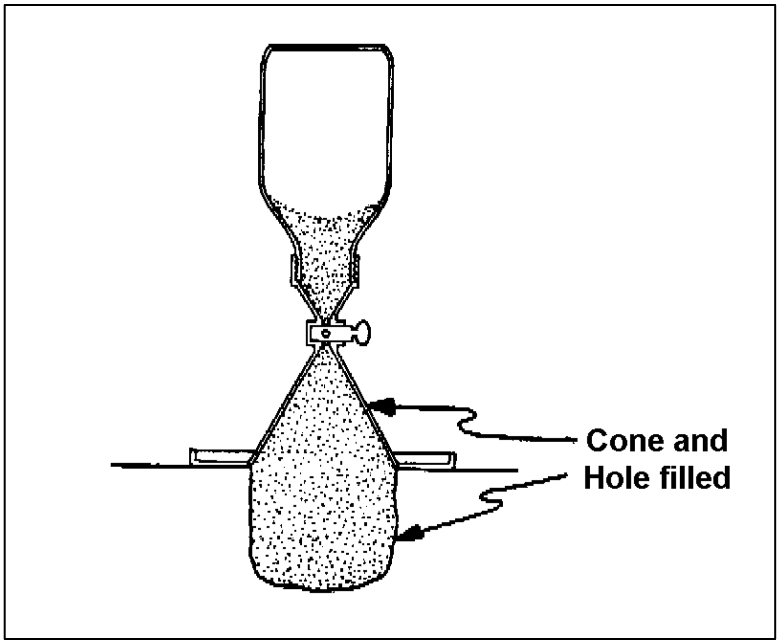
- avoid disturbing the sides or bottom of the hole to an extent that would leave large or irregular cavities; and

e. placing <u>all</u> of the material from the hole in an air-tight container.

2. **Measure the Volume of the Hole** by:
   a. filling the sand jar with standard sand and attaching the cone;
   b. weighing the sand jar, cone and recording this total weight;
   c. placing the cone (with the valve closed) and full jar over the hole and into the recessed area of the base plate, as shown below;



   d. making sure that no construction equipment that could cause vibrations is working nearby;
   e. opening the valve until the sand ceases to flow and then closing it, as shown below; and



f. removing and weighing the cone and jar with the remaining sand.

3. **Reference to (Method) “A” Proctor** by:
   a. weighing the total material removed from the hole;
   b. sieving the material through 3-inch and #4 sieves;
   c. determining the rock content (from the plus-#4 material); and
   d. determining the moisture content (from the pass-#4 material).

4. **Calculate**:
   a. the weight of the sand to fill the hole (original weight of filled apparatus, minus final weight);
   b. the volume of the hole (weight of sand to fill hole, minus the calibrated volume of the cone, divided by calibrated density of sand);
   c. the moisture content of the pass-#4 material (from the Speedy test);
   d. the total moisture content (including allowance for the plus-#4 rock);
   e. the wet density (total weight of the material removed, divided by the volume of the hole);
   f. the field dry density (from the wet density and moisture content); and
   g. the percent of maximum dry density achieved.

One-Point Proctors (Arizona-232)

The one-point Proctor test is used with an established family of moisture-density curves to determine the maximum density and optimum moisture of a material. It is used as a short-cut procedure for the regular 5-point Proctor. It is typically used in the field when there is a change in material or to verify the 5-point Proctor.

The equipment used for a one-point Proctor is the same as for a 5-point Proctor, including:

- the standard mold, base plate, extension collar and an extruder;
- the rammer;
- the mixing pan, spoons, straightedge and other tools;
- a balance scale;
- a #4 sieve; and
- the Speedy (or other) equipment for determining moisture content.

The basic procedures for the one-point Proctor are similar to those of the 5-point Proctor:

1. **Prepare the Sample** by drying it, breaking it up, sieving it to obtain the pass-#4 portion, and moistening it to slightly less than its anticipated optimum moisture.

2. **Mold the Specimen** by placing it in the mold in three equal layers, compacting each layer uniformly, removing the extension collar; and striking off the excess with the straightedge.

3. **Determine the Density and Moisture** by weighing the mold and specimen, subtracting the known weight of the mold, calculating the wet density, extruding and slicing the specimen to obtain a 20 or 26 gram portion from the center, and determining the moisture content from this portion.[5]

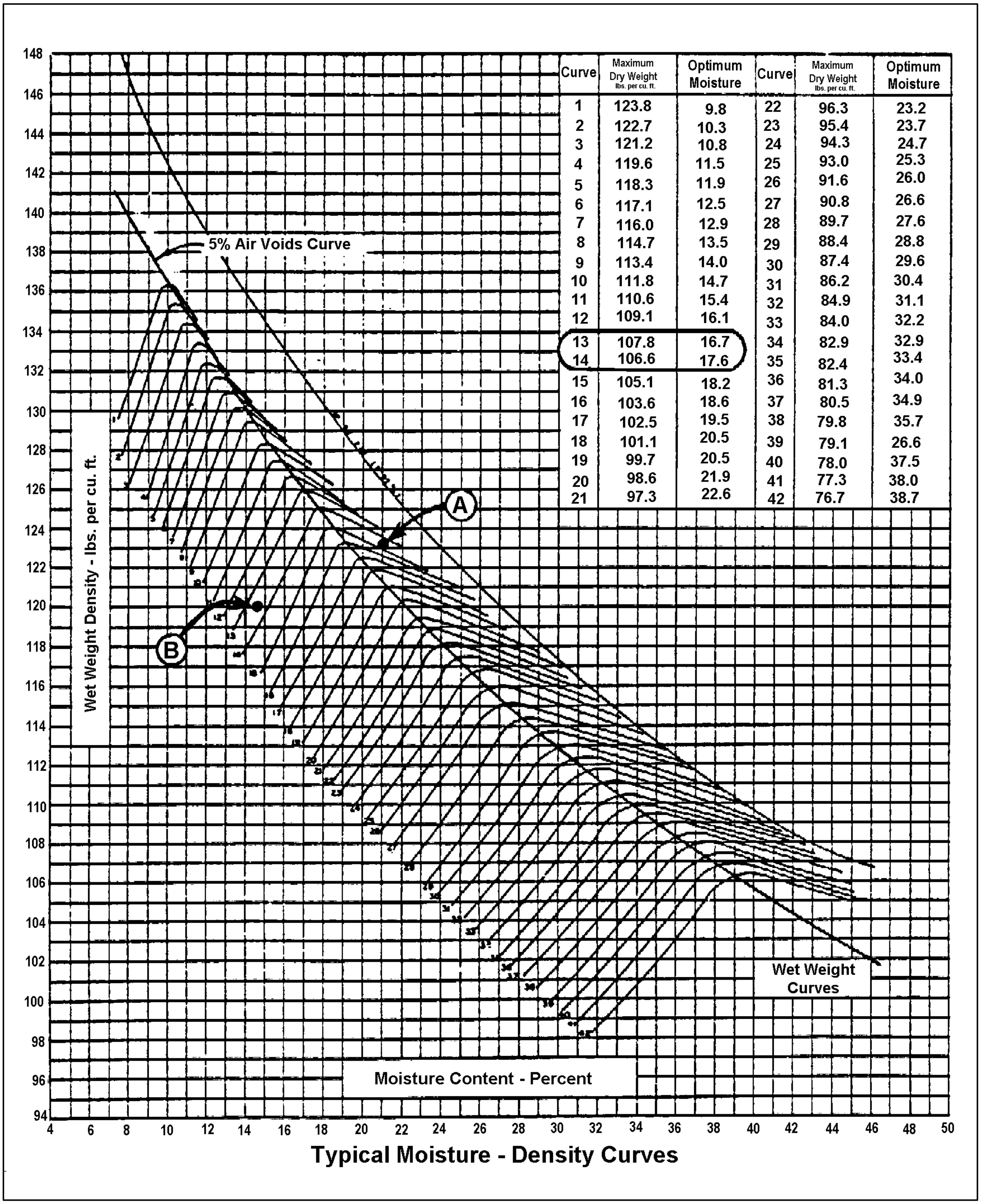
Rather than repeating the above procedure four more times at various moisture contents, a family of curves (as shown on page 20 is used to determine the maximum dry density and optimum moisture as follows:

4. **Plot the One-Point Proctor** on the family of curves:
   a. if the point falls to the right or "wet" side of the curves (such as point "A"), retest the material at a lower moisture content, but
   b. if the point falls to the left or "dry" side of the curves (such as point "B" with a Wet Density of 120 lbs./cu. ft. and a Moisture Content of 14.6%), continue to Step 5.

5. **Determine the Maximum Dry Density and Optimum Moisture** by:
   a. identifying the two curves that the point falls between (# 13 and # 14 for point "B"
   b. referring to the table in the upper right hand corner of the chart; and
   c . using the Maximum Dry Weights (107.8 and 106.6 lbs./cu.ft.) and Optimum Moistures (16.7 and 17.6%) to interpolate the maximum dry density and optimum moisture for the one-point Proctor (107.2 and 17.2% for point "B").

[5] Notice that it is not necessary to calculate the dry density. The family of curves provides for conversion from wet to dry density.

Family of Curves Chart



Curve	Maximum Dry Weight lbs. per cu. ft.	Optimum Moisture	Curve	Maximum Dry Weight lbs. per cu. ft.	Optimum Moisture
1	123.8	9.8	22	96.3	23.2
2	122.7	10.3	23	95.4	23.7
3	121.2	10.8	24	94.3	24.7
4	119.6	11.5	25	93.0	25.3
5	118.3	11.9	26	91.6	26.0
6	117.1	12.5	27	90.8	26.6
7	116.0	12.9	28	89.7	27.6
8	114.7	13.5	29	88.4	28.8
9	113.4	14.0	30	87.4	29.6
10	111.8	14.7	31	86.2	30.4
11	110.6	15.4	32	84.9	31.1
12	109.1	16.1	33	84.0	32.2
13	107.8	16.7	34	82.9	32.9
14	106.6	17.6	35	82.4	33.4
15	105.1	18.2	36	81.3	34.0
16	103.6	18.6	37	80.5	34.9
17	102.5	19.5	38	79.8	35.7
18	101.1	20.5	39	79.1	26.6
19	99.7	20.5	40	78.0	37.5
20	98.6	21.9	41	77.3	38.0
21	97.3	22.6	42	76.7	38.7

Section Three Quiz

1. In the Speedy moisture test, the two steel balls are used ... (Circle one or more)
   a. only when retesting material that included lumps after initial testing.
   b. in the 6-gram tester.
   c. in the 26-gram tester.
   d. all the time, in any size tester.

2. In what position should the Speedy tester be held as the cap and soil sample are placed on the tester? (Circle one)
   a. horizontal
   b. 45-degree diagonal
   c. vertical
   d. any position, as long as soil is not spilled

3. Which of the following is determined in the calibration procedure for the sand cone test? (Circle one or more)
   a. the volume of the jar
   b. the density of the sand
   c. the moisture content of the sand
   d. the volume of the cone
   e. the gradation of the sand

4. In the sand cone test for field density, the volume of the hole is determined by ... (Circle one)
   a. subtracting the initial reading from the final reading.
   b. subtracting the weight of the remaining sand from the original, total weight of sand; and multiplying by the calibrated conversion factor.
   c. subtracting the moisture content from the wet density.
   d. subtracting the weight of the remaining sand from the original, total weight of sand; subtracting the calibrated volume of the cone and dividing this by the calibrated density of the sand.

5. Which of the following aspects of a one-point Proctor test is <u>different</u> from a 5-point Proctor?
   a. the size and type of Proctor mold used
   b. the methods used to compact the specimen
   c. the procedures and calculations used to determine the wet density and moisture content
   d. the number of specimens compacted
   e. the use of a family of curves to determine the optimum moisture and maximum dry density

Section Three Quiz Answers

1. c. in the 26-gram tester

2. a. horizontal

3. b. the density of the sand
   d. the volume of the cone

4. d. subtracting the weight of the remaining sand from the original total weight of sand; dividing this by the calibrated density of the sand; and subtracting the calibrated volume of the cone.

5. d. the number of specimens compacted
   e. the use of a family of curves to determine the optimum moisture and maximum dry density.

Section Four: Testing Frequencies

Summarized below are the locations for testing frequencies of soils and aggregates, taken from Appendix C "Sampling Guide Schedule" in the 10/1/99 version of ADOT *Materials Testing Manual*.

Table 1 – Acceptance Sampling Guide for Soils

Pages 1 – 3: Sections 203, 501, 803, and 804

Table 2 – Acceptance Sampling Guide for Soils

Pages 4 - 23: Sections 203, 303, 304, 305, and 501 (up to page 9)
With and Without Contractor's Q.C.

Table 6 – Acceptance Sampling Guide for Soils

Pages 35 - 36: Sections 301, 302, and 304

Table 9 – Index of Materials

Pages 50 – 53

Certificates of Compliance or Analysis may be used in lieu of sampling or testing, or to supplement the sampling and testing process.

Requirements are stated in two documents:

- ADOT *Standard Specifications* Section 106.05, and
- Series 1000 Certificates, ADOT *Materials Testing Manual*.